Computer Engineering II

Microcontroller

Lecture Seven

Electrical Engineering Department
Third Stage

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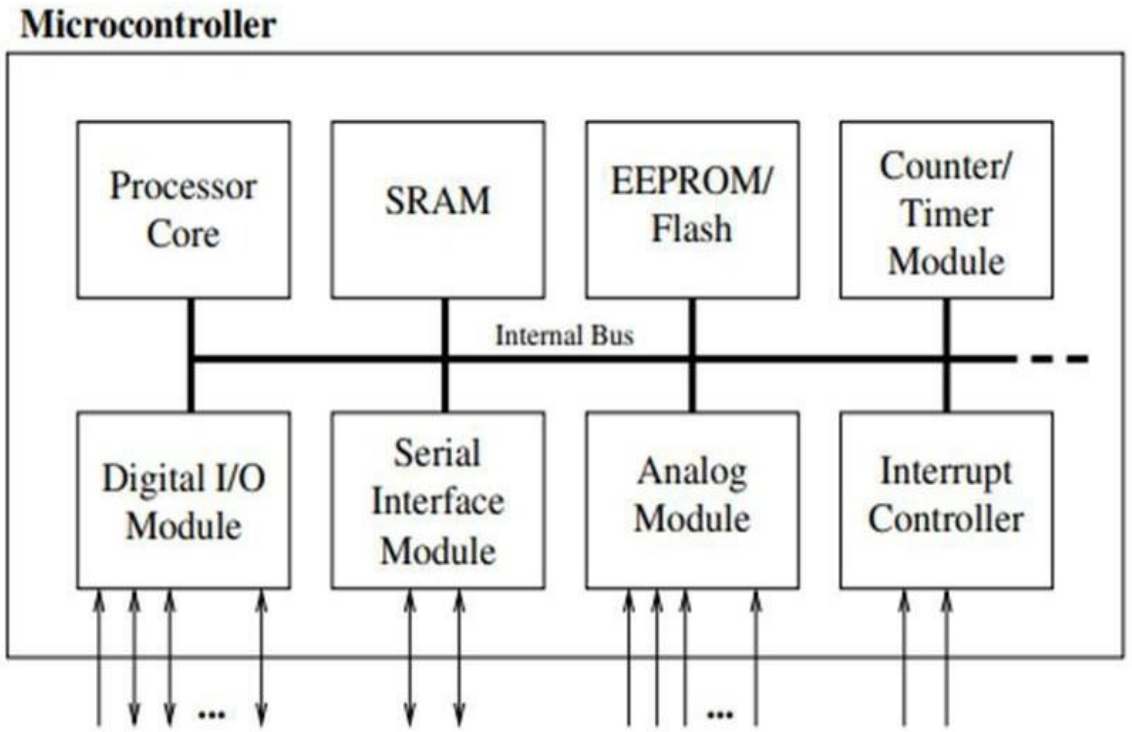
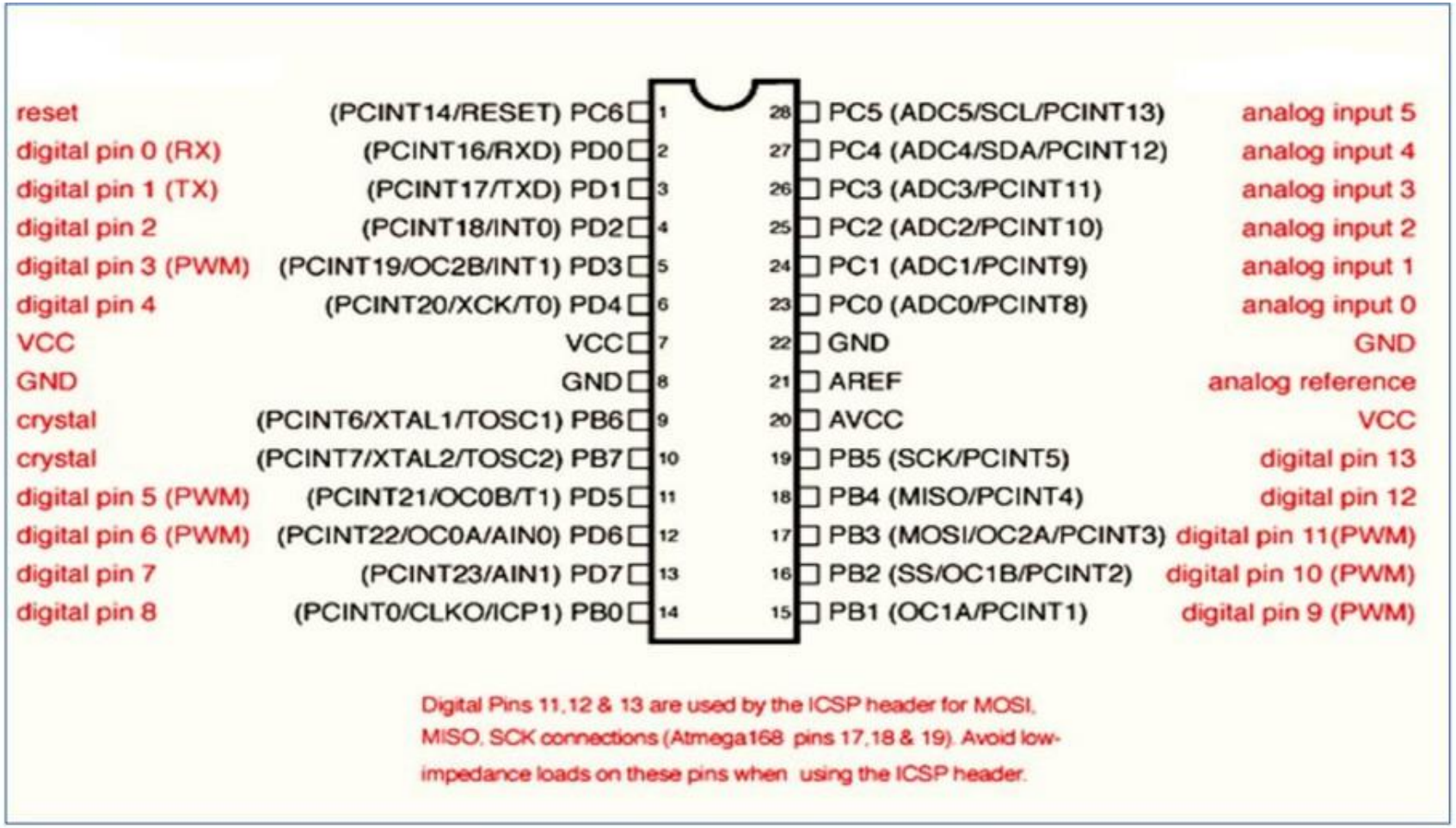
Microcontroller

- A Microcontroller (also called Embedded Computer) is a mini(but powerful) computer, embedded in a compact IC(Integrated Circuit) chip, contains on-chip processor(one or more), memory(i.e. RAM, ROM, EEPROM etc.) & programmable I/O Ports(used for multiple functions).
- The basic internal designs of microcontrollers are pretty similar. Figure 1. shows the block diagram of a typical microcontroller. All components are connected via an internal bus and are all integrated on one chip. The modules are connected to the outside world via I/O pins.



Microcontroller

- **Examples:**
- Microprocessor - Pentium, PowerPC chip in your computer.
- Microcontroller - 68HC11, 68332, MPC555.
- A microcontroller is essentially a microprocessor with several other features embedded onto a single chip
- Examples of things that use microcontrollers
- Automobiles, Automatic Cameras, CD player, etc.

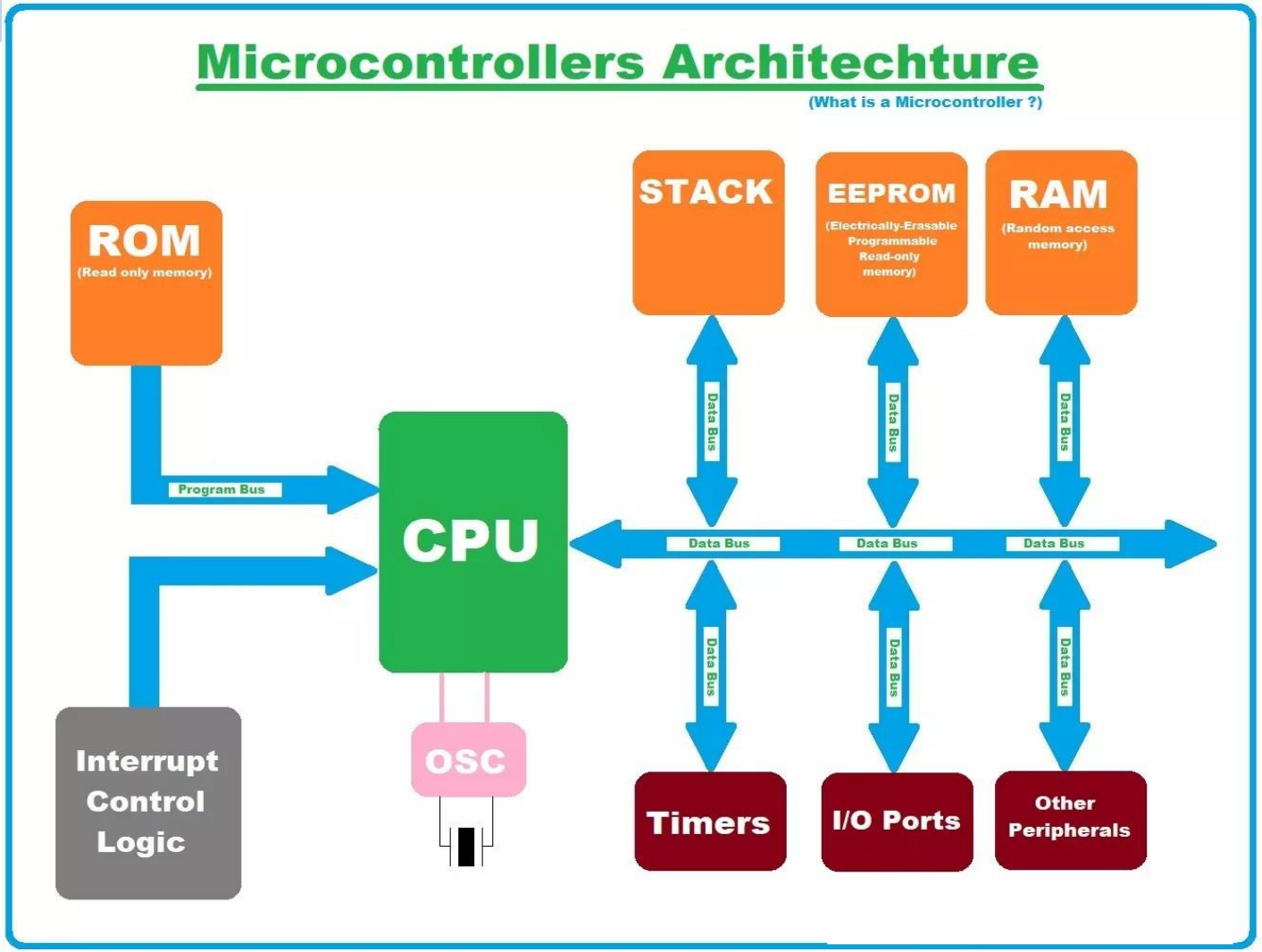


The pin diagram of Microcontroller

Why uses a microcontroller?

- 1. Reduce chip count.
- 2. Many applications do not require as much computing power.
- 3. Reduced power consumption.
- 4. Reduced design cost.
- In fact, industry sells 10 times as many microcontrollers as microprocessors.
- **What are the parts of a microcontroller?**
- 1. CPU
- 2. Memory
- 3. I/O (Input/Output)

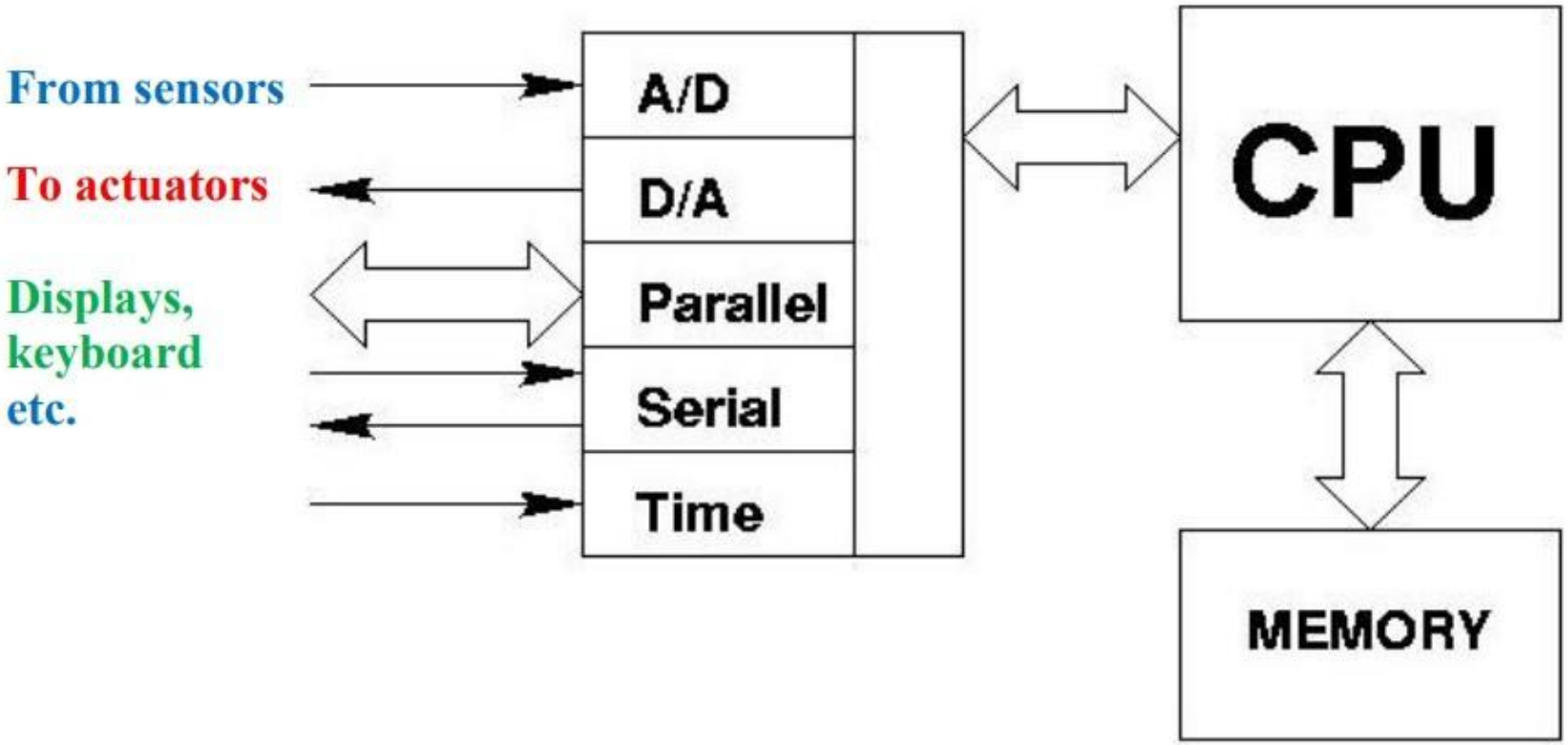
Microcontrollers Architecture



- RISC Architecture is considered the most advanced Microcontrollers Architecture so far & it comes with few standard components, which we will discuss here.
- Here's a Flow Diagram of Microcontroller's Architecture:

- As you can see in previous figure, Microcontroller's Architecture consists of:
  - CPU(Central Processing Unit).
  - ROM(Read-only memory).
  - RAM(Random-access memory).
  - EEPROM(Electrically-Erasable Programmable Read-only memory).
  - Ports I/O.
  - Timers.
  - Interrupts.

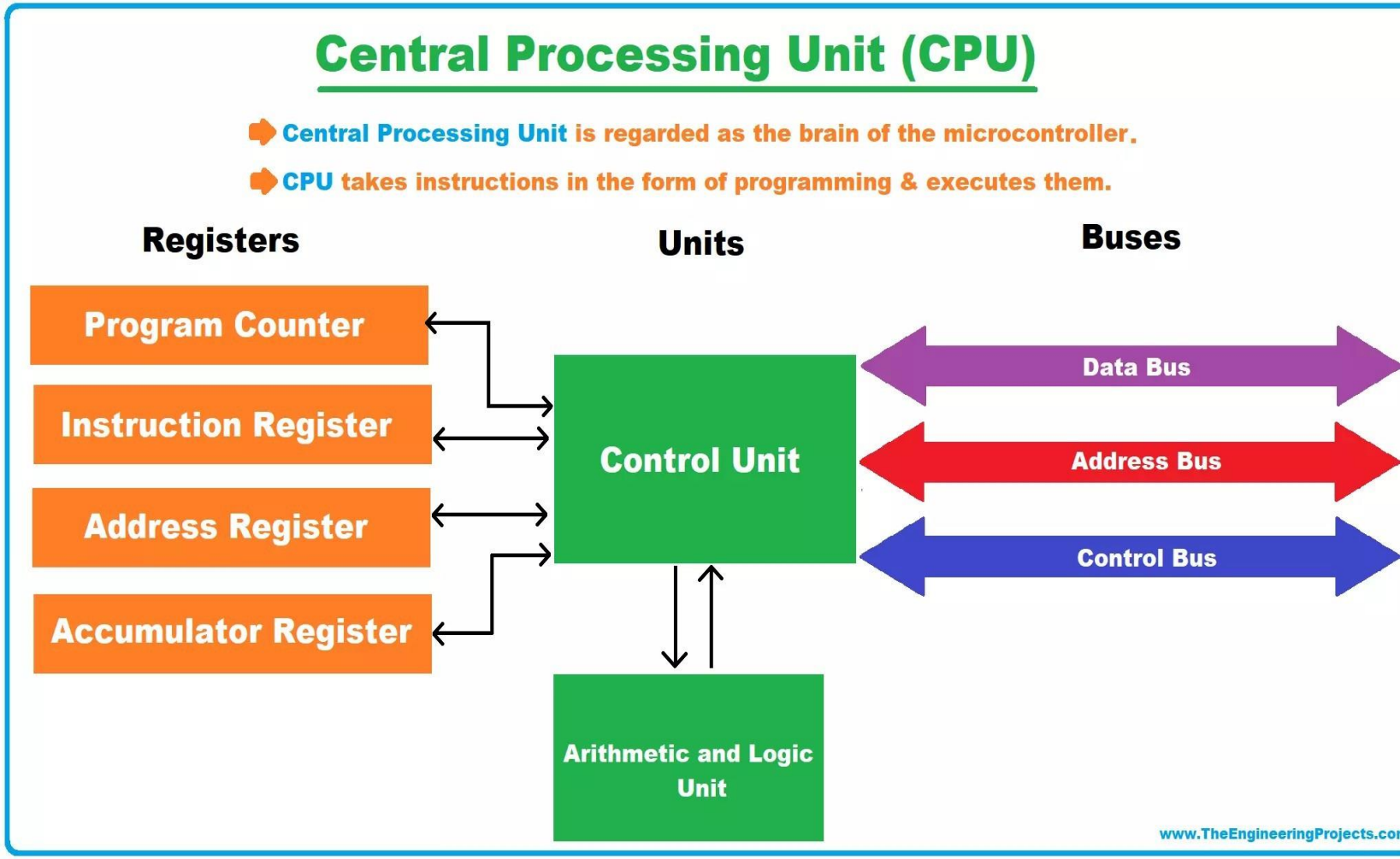
Parts of A Microcontroller



Basic a microcontroller diagram

Parts of Microcontroller

- **CPU**
  - Central Processing Unit
  - “Smart part” of the computer that processes data and makes decisions Has all the parts of a
  - normal microprocessor.



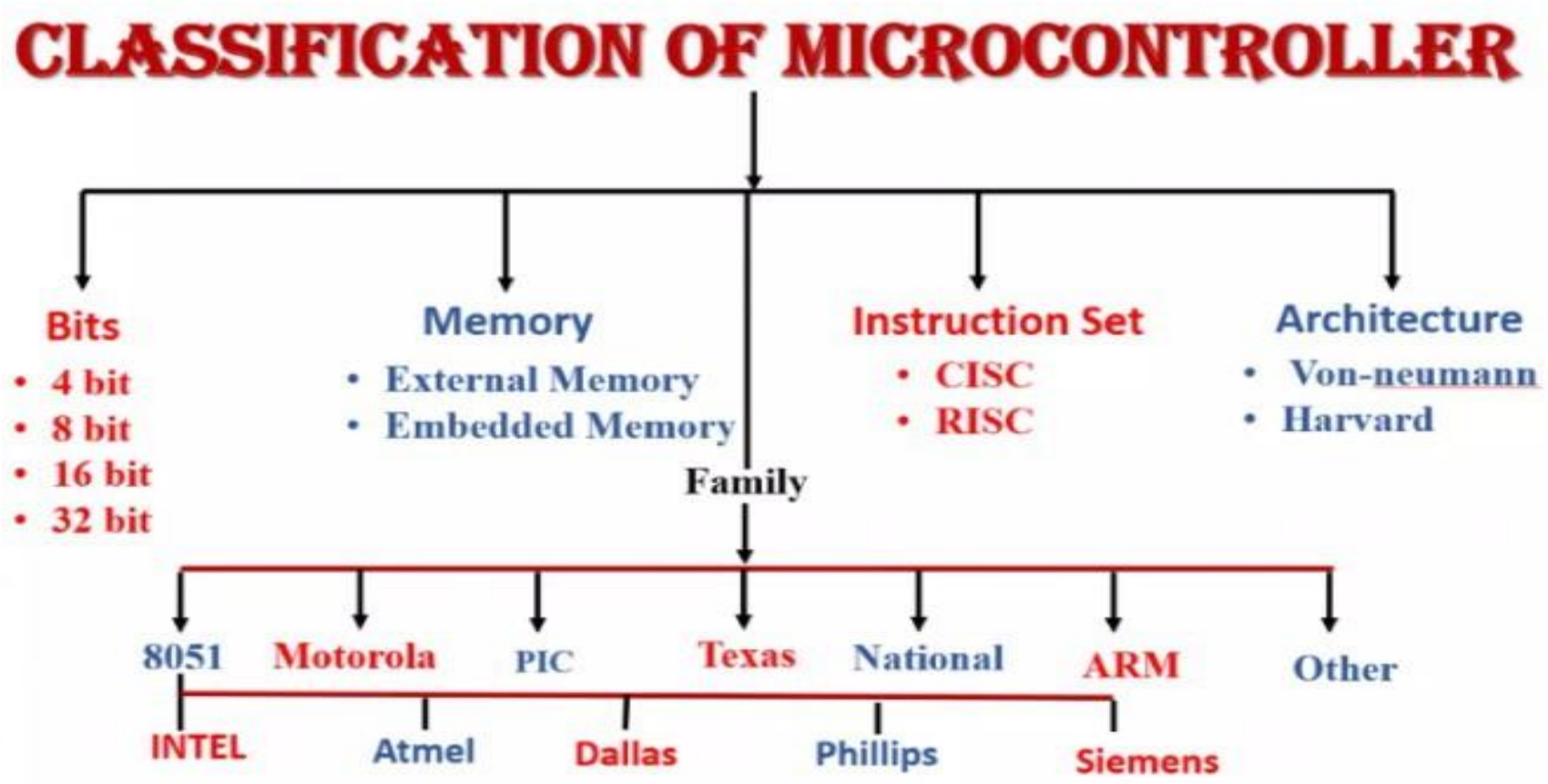
Parts of Microcontroller

- **Memory**
- RAM – Random Access Memory – Storing data while microcontroller is running
- ROM – Read Only Memory – Store bootup data information
- EEPROM or EPROM – Persistent storage of data parameters that can be rewritten
- Example: Alarm clock saving the time when the power goes off.
- **I/O**
- Methods to interact with the world outside the microcontroller
- A typical CPU takes up only a small portion of the actual silicon real estate of a microcontroller
- leaving additional space for other features.
- **Example:**
- A/D – Analog to Digital Converter ,Temperature Sensor , Display controller , Timing circuits , Communication circuits , Parallel, Serial, Ethernet

Microcontroller Modules

- Microcontrollers typically consist of the following modules:
- **1. Processor Core**: The CPU handles tasks like arithmetic, control, and registers (stack pointer, program counter, accumulator, etc.).
- **2. Memory:** Divided into program and data memory, with some using DMA controllers for data transfer between peripherals and memory.
- **3. Interrupt Controller**: Manages external and internal interrupts, helping to conserve power, especially with sleep modes.
- **4. Timer/Counter**: Used for timestamping, measuring intervals, or event counting, often including PWM outputs for motor control or analog conversion.
- **5. Digital I/O:** Provides parallel digital input/output pins, varying in number depending on the microcontroller.
- **6. Analog I/O:** Many microcontrollers have analog/digital converters with 2-16 channels and resolutions of 8-12 bits.
- **7. Interfaces:** Include serial interfaces for programming and communication with external devices.
- **8. Watchdog Timer**: Ensures system safety by resetting the controller during software errors.
- **9. Debugging Unit**: Hardware for remote debugging, preventing application code from disrupting the process.

Classification of Microcontroller



Classification of Microcontroller

- Microcontrollers are divided into various categories based on memory, architecture, bits and instruction sets. Following is the list of their types
- Bit
- Based on bit configuration, the MC is further divided into three categories.
- 8-bit microcontroller - This type of microcontroller is used to execute arithmetic and logical operations like addition, subtraction, multiplication division, etc. For example, Intel 8031 and 8051 are 8 bits microcontroller.
- 16-bit microcontroller - This type of microcontroller is used to perform arithmetic and logical operations where higher accuracy and performance is required. For example, Intel 8096 is a 16-bit microcontroller.
- 32-bit microcontroller - This type of microcontroller is generally used in automatically controlled appliances like automatic operational machines, medical appliances, etc.

Classification of Microcontroller

- **Memory**
- Based on the memory configuration, the microcontroller is further dividedinto two categories.
- **External memory microcontroller** - This type of microcontroller is designed in such a way that they do not have a program memory on the chip. Hence, it is named as external memory microcontroller. For example: Intel 8031 microcontroller.
- **Embedded memory microcontroller** - This type of microcontroller is designed in such a way that the microcontroller has all programs and data memory, counters and timers, interrupts, I/O ports are embedded on the chip. For example: Intel 8051 microcontroller.

Classification of Microcontroller

- **Instruction Set**
- Based on the instruction set configuration, the microcontroller is further divided into two categories.
- **CISC** - CISC stands for complex instruction set computer. It allows the user to insert a single instruction as an alternative to many simple instructions.
- **RISC** - RISC stands for Reduced Instruction Set Computers. It reduces the operational time by shortening the clock cycle per instruction.

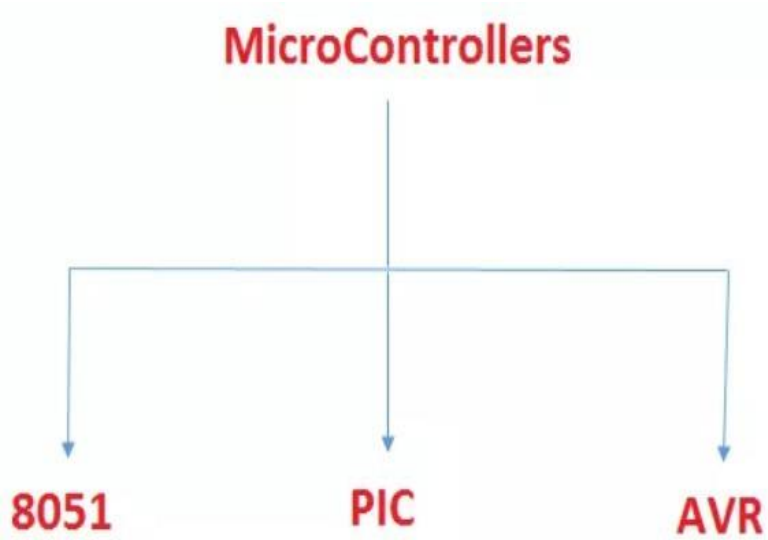
Classification of Microcontroller

- Classification Of Microcontroller According to Memory Architecture
- According to Memory Architecture there are two type of
- Microcontroller. Harvard Memory Architecture.
- Von Neumann Memory Architecture
- Harvard Memory Architecture: In Harvard architecture separate storage and signal Buses are provided for different set of instructions(program) and data.
- Von Neumann architecture: In Von Neumann architecture, one Bus is exists for both instruction and data. So, the CPU does only one operation at a time.
- It either fetches an instruction from memory, or performs read/write operation on data. So both operations (instruction fetch and a data operation) cannot occur simultaneously because they sharing a common bus.

Classification of Microcontroller : Types of Microcontrollers based on Manufacturer

1. 8051 Microcontroller

- 8051 microcontroller is a 40 pin 8 bit microcontroller invented by Intel in 1981.
- 8051 comes with 128 bytes of RAM and 4KB of built in ROM.
- Based on priorities, 64 KB external memory can be incorporated with the microcontroller.
- A crystalline oscillator is embedded on this microcontroller which comes with a frequency of 12 MHz.
- Two 16 bit timers are integrated in this microcontroller that can be used as a timer as well as a counter.
- 8051 consists of 5 interrupts including External interrupt 0, external interrupt 1, Timer interrupt 0, timer interrupt 1 and Serial port interrupt.
- It also consists of four 8 bits programmable ports.



2. PIC Microcontroller

Microchip Technology invented the PIC (Peripheral Interface Controller) microcontroller, which uses the Harvard architecture. Known for its low cost, serial programmability, and wide availability, it stands out for industrial use. The PIC microcontroller integrates essential components like ROM, CPU, timers, interrupts, I/O ports, and registers (which also function as RAM). It also includes special-purpose registers on-chip. Its low power consumption makes it particularly suitable for industrial applications, and Microchip continuously upgrades its products to meet customer needs.

3. AVR

AVR (Advanced Virtual RISC) is a microcontroller developed by Atmel in 1996, supporting the Harvard architecture, where program and data are stored separately. It was one of the early microcontrollers to use on-chip flash memory for program storage. The architecture was designed by Vegard Wollan and Alf-Egil Bogen. The first AVR-based controller was the AT90S8515, while the AT90S1200 was the first commercially available model in 1997. AVR integrates flash, EEPROM, and SRAM on a single chip, eliminating the need for external memory. It includes a watchdog timer and multiple power-saving sleep modes, making it reliable and user-friendly.

Microcontrollers Working

✅ **Microcontroller Operating Principle (Step-by-Step):**

1.Power ON:

When the microcontroller is powered on, the quartz oscillator is activated to generate the clock signal that determines the instruction execution speed.

2.System Initialization:

Internal capacitors are charged, registers are initialized, and the program stored in memory (usually ROM) starts running.

3.Instruction Fetch:

The microcontroller fetches the first instruction from memory.

4.Instruction Execution:

The fetched instruction is executed — for example, turning on a motor, reading a sensor, or sending a signal.

5.Continuous Loop:

The fetch-execute cycle continues at very high speed (within nanoseconds).

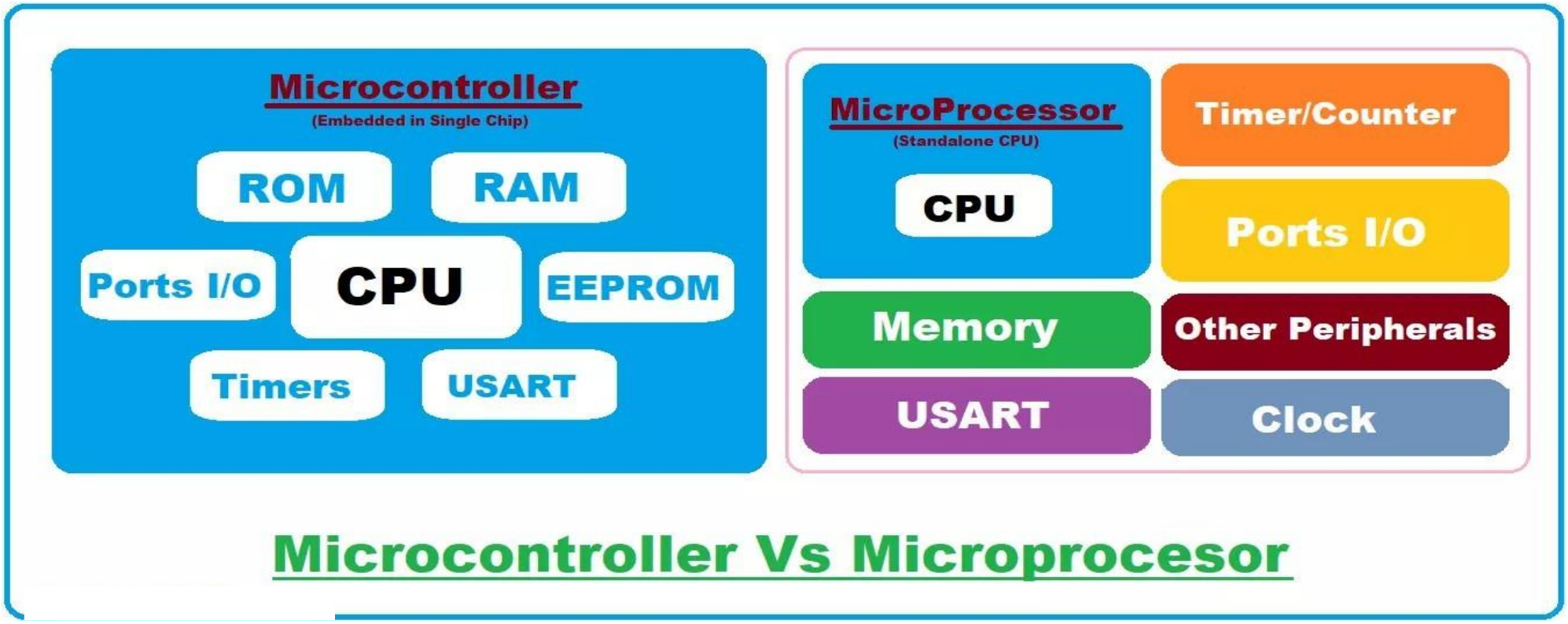
6.Interaction with Environment:

It reads signals from **input devices/sensors** (e.g., temperature or light), and sends control signals to **output devices** (e.g., LEDs or motors) according to the program instructions.

Differences between Microprocessors and Microcontrollers

Parameter	Microprocessor	Microcontroller
Definition	IC that has only CPU inside it and RAM, ROM and other peripherals need to be added externally	IC that has integration of CPU RAM, ROM and other peripherals
Tasks used	General purpose	Specific purpose
Preference	Relationship between input and output is not clearly defined	Relationship between input and output is clear defined
Suitability for embedded applications	Not suitable	Ideally suitable due to lo power consumptions
Price	Costlier	Cheaper
Speed	High (1Ghz)	Slow (20-50Mhz)
Memory	External (in GBs)	KBs of internal for RAM and ROM

Microcontroller Vs Microprocessor



Microcontroller Characteristics

- 1. Advanced Microcontrollers: Some modern microcontrollers have a complex design and support word lengths greater than 64 bits.
- 2. Integrated Components: Microcontrollers contain built-in components such as EPROM, EEPROM, RAM, ROM, timers, I/O ports, and a reset button. RAM stores data, while ROM stores programs and parameters.
- 3. CISC Architecture: Modern microcontrollers use the CISC (Complex Instruction Set Computer) architecture, which employs macro-type instructions to replace multiple smaller ones.
- 4. Efficient Power Consumption: Modern microcontrollers consume much less power compared to older models.
- 5. Low Voltage Operation: They can operate at voltages as low as 1.8V to 5.5V.
- 6. Advanced Flash Memory: EPROM and EEPROM are advanced flash memory features in modern microcontrollers, offering reliability.
- 7. EPROM vs. EEPROM: EPROM is faster and allows for unlimited erase and write cycles, making it more user-friendly than EEPROM.

Microcontrollers Applications

- Peripheral controller of a PC
- Robotics and Embedded systems
- Bio-medical equipment
- Communication and power systems
- Automobiles and security systems
- Implanted medical equipment
- Fire detection devices
- Temperature and light sensing devices
- Industrial automation devices
- Process control devices
- Measuring and Controlling revolving objects

Thank You